

Award Number: DAMD17-00-1-0245

TITLE: Robust Detection of Masses in Digitized Mammograms

PRINCIPAL INVESTIGATOR: Lihua Li, Ph.D.

CONTRACTING ORGANIZATION: University of South Florida  
Tampa, Florida 33620

REPORT DATE: June 2003

TYPE OF REPORT: Annual Summary

PREPARED FOR: U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;  
Distribution Unlimited

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20031031 009

**REPORT DOCUMENTATION PAGE**Form Approved  
OMB No. 074-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

**1. AGENCY USE ONLY**  
(Leave blank)**2. REPORT DATE**  
June 2003**3. REPORT TYPE AND DATES COVERED**  
Annual Summary (15 May 02 - 15 May 03)**4. TITLE AND SUBTITLE**Robust Detection of Masses in Digitized  
Mammograms**5. FUNDING NUMBERS**

DAMD17-00-1-0245

**6. AUTHOR(S)**

Lihua Li, Ph.D.

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**University of South Florida  
Tampa, Florida 33620

E-Mail: lilh@moffitt.usf.edu

**8. PERFORMING ORGANIZATION  
REPORT NUMBER****9. SPONSORING / MONITORING  
AGENCY NAME(S) AND ADDRESS(ES)**U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012**10. SPONSORING / MONITORING  
AGENCY REPORT NUMBER****11. SUPPLEMENTARY NOTES****12a. DISTRIBUTION / AVAILABILITY STATEMENT**

Approved for Public Release; Distribution Unlimited

**12b. DISTRIBUTION CODE****13. ABSTRACT (Maximum 200 Words)**

This project is to develop a robust computer aided diagnosis (CAD) system for mass detection with high sensitivity and specificity in digitized mammograms. The research scope in past year is to evaluate the detection performance and robustness of CAD system. Several major progresses have been made including (1). In addition to the training database, two independent testing databases were generated for evaluation. (2). Two testings and comparisons were made between the algorithms before and after the modifications using the methods developed in this project research in past two years: one on performance testing, another on robustness testing. A set of FROC curves was generated. It is demonstrated that the CAD system developed in this project consistently outperformed the CAD method we developed before both in detection performance and generalizability.

**14. SUBJECT TERMS**Breast Cancer, Mass, Detection, CAD, Mammography, Robust, Adaptive,  
Segmentation, Classification**15. NUMBER OF PAGES**

9

**16. PRICE CODE****17. SECURITY CLASSIFICATION  
OF REPORT**  
Unclassified**18. SECURITY CLASSIFICATION  
OF THIS PAGE**  
Unclassified**19. SECURITY CLASSIFICATION  
OF ABSTRACT**  
Unclassified**20. LIMITATION OF ABSTRACT**  
Unlimited

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## INTRODUCTION

This project is to develop a robust computer aided diagnosis (CAD) system for mass detection with high sensitivity and specificity in digitized mammograms. As listed in the Statement of Work, the research scope in the third year of project is to generate databases and use them for detection performance and robustness evaluation. The evaluation strategy taken in this research is to compare the detection sensitivity/specificity and the dependency of detection performance on database selection between old and newly developed CAD algorithm in this project by using FROC analysis.

## BODY

**Objective 1:** *to have typical databases for different evaluation purpose.*

### **Accomplishments:**

Two databases were generated in this evaluation study.

#### **Database I for detection performance evaluation:**

The mammograms in this database were originally digitized by a DBA digitizer at 60  $\mu\text{m}$  and 16 bit gray scale. Because the new algorithm proposed in this project was developed on Lumisys data, a mapping from DBA data format to Lumisys data format was taken before the evaluation of new algorithm. The database used in this FROC study consists of three datasets: 106 negative cases, 50 benign cases and 58 minimal cancer cases. Among the 50 benign cases, 32 cases are abnormal in terms of mass. 39 out of 58 minimal cancer cases are with masses.

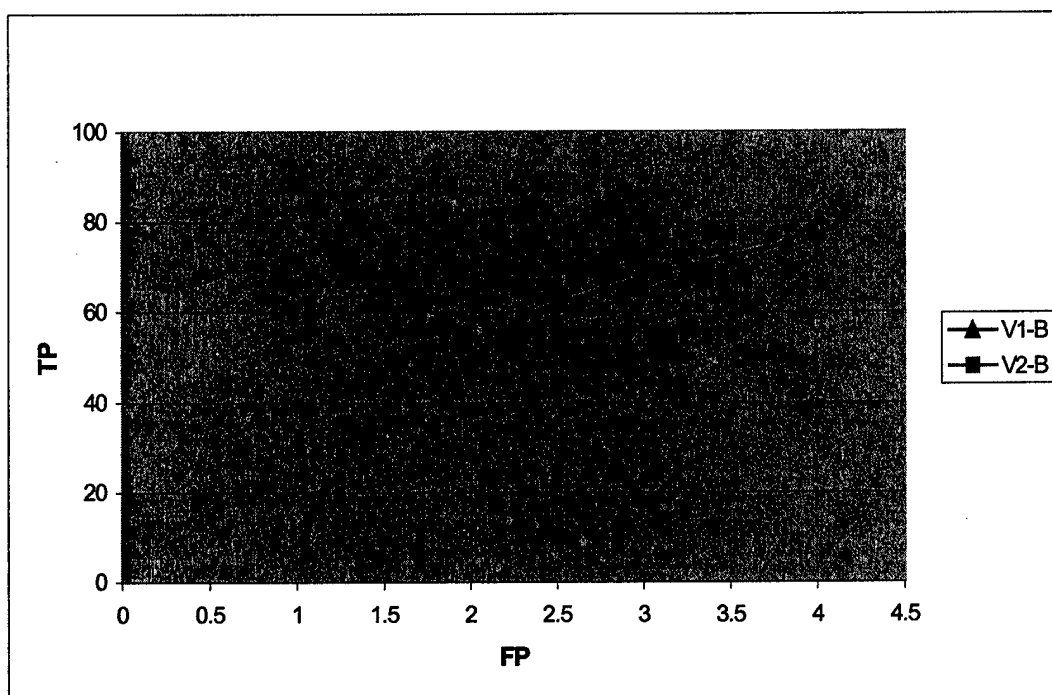
#### **Database II for detection robustness evaluation:**

This database are digitized by a Lumisys digitizer at 60  $\mu\text{m}$  resolution with 15 bits gray scale. They are subsampled by a factor of 3 to reduce the image size for mass detection, which approximately corresponds to 180  $\mu\text{m}$  in spatial resolution. Because the detection algorithm before the modification of this project's research was developed for DBA data, a mapping from Lumisys data format to DBA data format was taken before the evaluation of old algorithm could be made. This database was randomly split into two datasets for the testing of algorithm generalizability. The first dataset used in this FROC study consists of 102 cases, in which 31 cases are abnormal in terms of masses. The second dataset has 96 cases and 29 of them are abnormal. Among the abnormal cases, 61% the abnormal cases are benign and 39% are malignant in dataset I as compared to 18% benign and 82% malignant in dataset II.

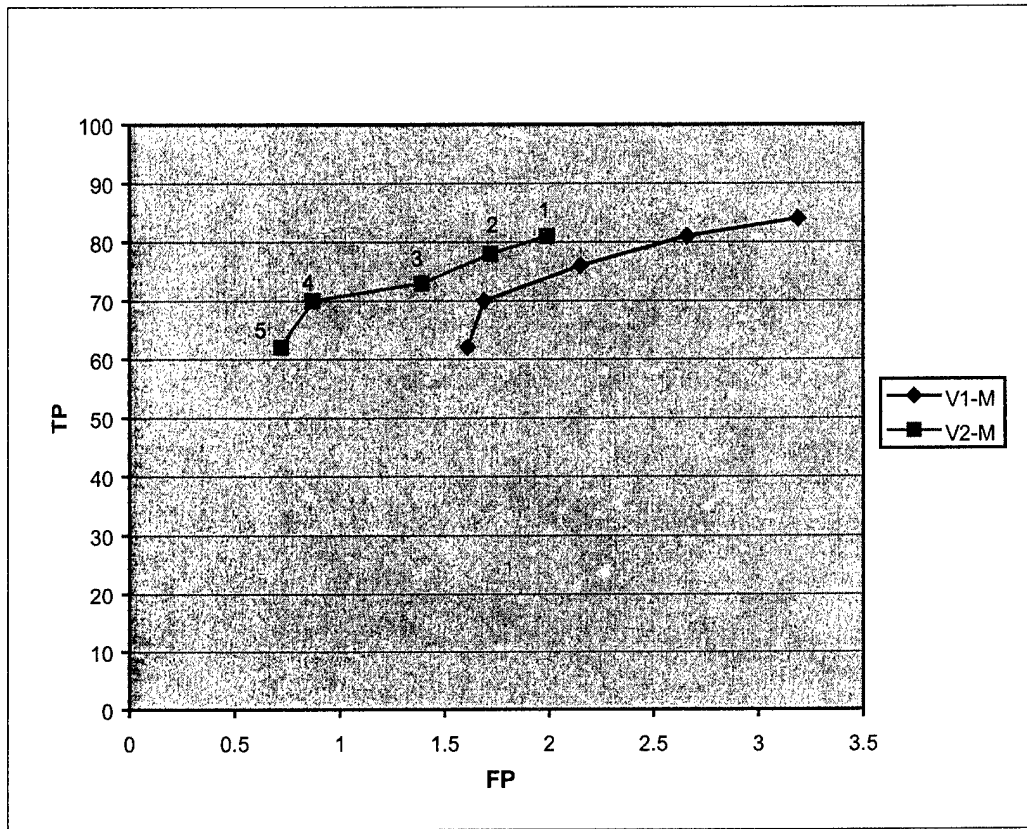
**Objective 2:** to evaluate the detection performance improvement of CAD system.

**Accomplishments:**

The evaluation of both algorithms were taken on benign, minimal cancer and normal case datasets respectively. The FROC curves of case detection sensitivity versus false-positive signals are shown in the Figure 1 and Figure 2. The consistence of detection performance improvement of the algorithm developed in this project compared to the old algorithm we developed before is observed. The false positive rate of two algorithms on negative dataset was also obtained as listed in the Table 1 and Table 2. It is noticed that new algorithm generated much less false positive signals.



**Figure 1. FROC curves on benign dataset in Database I, where V1-B and V2-B are the results of old and new detection algorithms respectively.**



**Figure 2. FROC Curves on minimal cancer cases in Database I, where V1-M and V2-M are the results of old and new algorithm respectively.**

**Table I. FPs of old algorithm on Negative Cases at five different working points.**

	1	2	3	4	5
<b>FP</b>	2.95	2.69	1.95	1.85	1.65

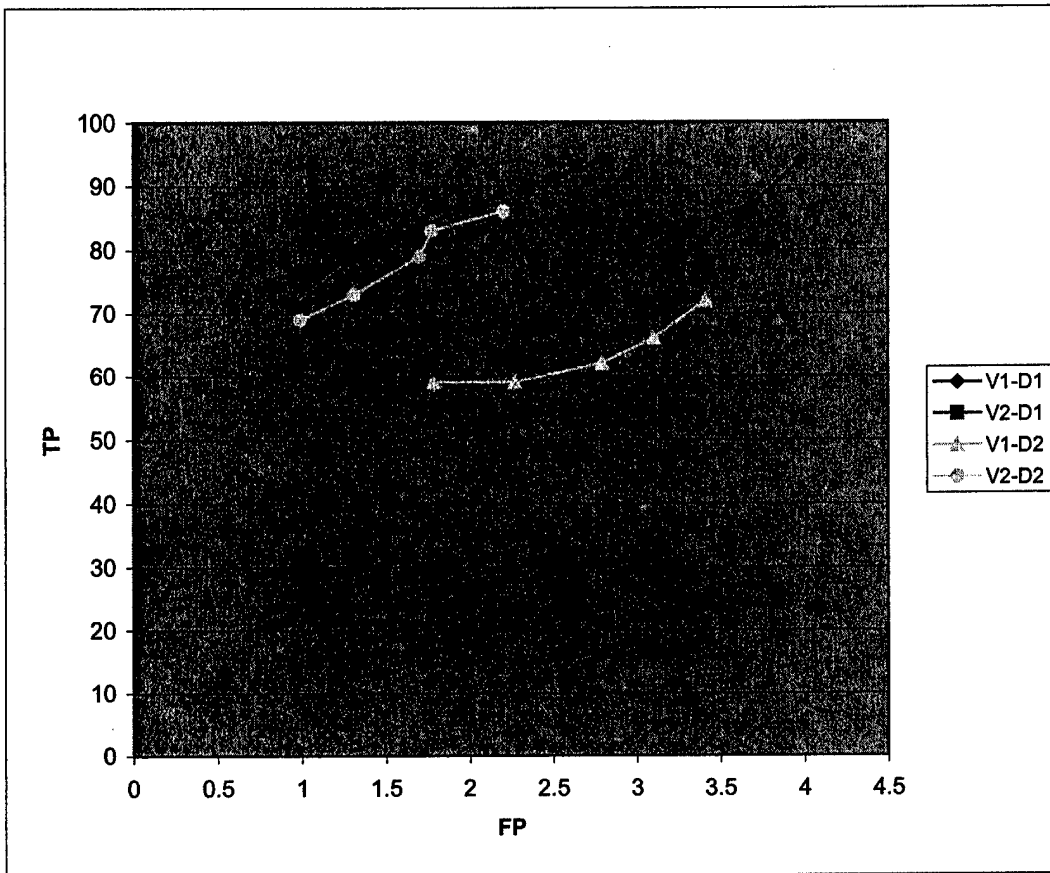
**Table 2. FPs of new algorithm on Negative Cases at five different working points.**

	1	2	3	4	5
<b>FP</b>	2.29	2.18	1.91	1.38	0.95

**Objective 3: to evaluate the robustness of CAD system**

**Accomplishments:**

To evaluate the improvement of detection robustness, two generation algorithms were tested and compared on the two datasets in Database II, in which the first dataset used in this FROC study consists of 102 cases, where 31 cases are abnormal in terms of masses; the second dataset has 96 cases and 29 of them are abnormal. Among the abnormal cases, 61% the abnormal cases are benign and 39% are malignant in dataset I as compared to 18% benign and 82% malignant in dataset II. The FROC curves of detection results by using old and newly developed algorithms in this project are shown in Figure 3. It is observed that the detection performance of both algorithms drops on the second dataset compared to the first dataset. For example, the case detection sensitivity of first generation algorithm drops from 84% at 3.32 false-positive signals per image to 72% at 3.41 FPs per image. The performance also drops for the new algorithm from 87% at 2.05 FPs to 86% at 2.20 FPs. On the overall, the following facts were observed, (1) the big improvement of detection performance of newly developed algorithm over the old algorithm is consistently obtained on both datasets and as that shown in the testing on Database I. To some extent, the improvement is even bigger for second dataset; (2) the new algorithm has a less drop in performance compared to the old algorithm, i.e. the new algorithm demonstrates a better robustness to the variation of database characteristics. By reviewing the mammogram dataset and its detection results, it is found that the major cause of detection performance drop is the cases in second dataset are more difficult than that of first dataset, where there are 82% cases are malignant as opposed to only 39% cases are malignant in first half data.



**Figure 3. FROC curves of detection by using old and new algorithms on two independent datasets.**

### KEY RESEARCH ACCOMPLISHMENTS

1. Two databases were generated for CAD system evaluation.
2. An evaluation of detection performance was taken. A big improvement was obtained by using the new methods developed in this project.
3. An evaluation of CAD system robustness was taken. It is observed that the new CAD system developed in this project has a much better detection generalizability.

## REPORTABLE OUTCOMES

### *1. Presentation and/or proceedings paper*

- (a) Lihua Li, Robert A. Clark and Jerry A. Thomas, "Improving algorithm robustness for mass detection in digital mammography," Proceedings of Era of Hope, Department of Defense Breast Cancer Research Program meeting, Vol. 1, Sept. 25-28, 2002.
- (b) Yong Chu, Lihua Li, D.B. Goldgof, Y. Qiu, et al., "Classification of masses on mammograms using support vector machine," Proceedings of SPIE Medical Imaging, 2003.

### *2. Fundings Applied*

- (a) "Computer Aided Diagnosis of Focal Asymmetric Density", a project in Program Grant titled "Breast Imaging and Computerized Analysis Program" submitted to NCI, 2002.

### *3. Funded Grant*

- (a) "Computerized Analysis and Detection of Missed Cancer in Screening Mammogram" was funded by USARMY. (IDEA AWARD)

## CONCLUSIONS

The great variation of characteristics of mammograms and masses hinders us in developing a high detection performance and more generalizable CAD system. The typical variations between different mammograms result either from the imaging process (such as film exposure, film label), digitization process (such as spatial / intensity resolution, response function to optical density), or most importantly the inherent breast tissue characteristics. The variations of masses include its size, contrast, shape, location, intensity pattern and its relation to the surrounding tissues. The research work taken in third year of this project is to generate databases and use them for detection evaluation of CAD system in terms of performance improvement and generalizability. The evaluation results demonstrated that the algorithm developed in this project is much better than our old (first generation) algorithm.